Epigeic activity of eight common Collembola species in spruce forests and clearings after bark beetle outbreaks in the Šumava National Park, Czech Republic

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Surface activity of eight common epigeic species of Collembola were studied in spruce forests, dead spruce forests and clearings in the Šumava National Park, South Bohemia, Czech Republic: *Lepidocyrtus lignorum*, *Leidocyrus cyaneus*, *Pogonognathellus longicornis*, *Tomocerus minutus*, *Tetracanthella stachi*, *Allacma fusca*, *Entomobrya nivalis*, and *Dicyrtomina minuta*. Five pitfall traps were exposed at each of the 9 sites in the summer and autumn periods to study the impact of spruce forest die-off after bark beetle attack (dead forests) and on clearings. Material comprising 79 435 specimens was evaluated in this study using the non-parametric Kruskal-Wallis test for comparing Collembola activity between the sites and seasons. Complete linkage (Euclidean distances) cluster analysis was used for comparing the collembolan activity in all nine sites. Collembola reacted on the environmental changes either by decreased activity in the dead forests and reaching the lowest activity on the clearings (*A. fusca* and *D. minuta*), or by increasing their activity in the dead forests and reaching highest activity in the clearings (*L. cyaneus*), or by reaching highest activity in dead forests and almost missing on the clearings (*E. nivalis*, *T. stachi*). *L. lignorum*, *P. longicornis* and *T. minutus* had high levels of activity in all types of sites, but the differences between sites were not significant.

Keywords: Spruce forests, dead forests, clearings, epigeic Collembola, bark beetle outbreak.

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Introduction

Climax spruce forests and plantations are predominant in the Šumava (Bohemian Forest) National Park. In the last decades they have been heavily attacked by the bark beetle *Ips typographus* L.. This lead to spruce forest die-off in large areas of the national park, including the most valuable climax forests in the highly protected Zone I. Two different management practices were applied in the attacked forests. One part of the dead forests was left without felling the dead trees for further successive development (mainly in Zone I), the second part (in the less protected Zone II) was cut down and the clearings (without logs) were planted by beech, spruce and rowan seedlings. A complex scientific project was focused on the impact of different forest management comparing the dead forests with standing dead trees and the clearings. The botanical part of the project dealt with the changes in the understory, fungi and decomposition processes in soil, the soil zoological part compared the soil animal communities in the climax spruce forest not attacked by the bark beetles with the dead forests and clearings of different age. We have focused in our study on the surface activity of the eight most common epigeic springtails in the differently managed spruce forests, dead forests and clearings.

The main goals of our study were:

1. To study the epigeic activity of eight common Collembola species in undamaged and dead spruce forests and clearings in the Šumava National Park;
2. To describe the activity changes in the studied species of Collembola;
3. To relate the established activity changes to the spruce forest management after the bark beetle attack.

Material and methods

The studied localities are situated in the Šumava (Bohemian Forest) National Park, South Bohemia, in the area delimited by the mountains Studená hora, Březník, Špičník and Blatný vrch in the protected Zone I of the national park. The whole Šumava (Bohemian

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Forest) mountain system together with the adjacent parts in Bavaria and Austria is forming one geomorphological unit formed by crystalline shales, granites and syenitediorites. All sites were located between 1180-1310 m a.s.l. Soils are represented by cambisolic podsols, and podsols predominate above 1250 m a.s.l. Many of the climax spruce forests have boggy organic soils dominated by *Sphagnum* moss. The climate is distinctly cool, the mean annual temperature above 1300 m a.s.l. is 3 °C and the annual precipitation 1400 mm (Culek, 1996).

List of localities

Undamaged forests:
EO: SE slope, 1 km south of the Ptačí nádrž near Malá Mokrůvka, 1210-1220 m a.s.l., plant community *Calamagrostio villosae – Piceetum fagetosum.*
AO: S slope of Studená hora, 1255 m a.s.l., plant community *Calamagrostio villosae – Piceetum fagetosum.*

Dead forests:
EL1: SSW slope under the road to Roklanská hájovna, 1240 m a.s.l., former plant community *Calamagrostio villosae – Piceetum fagetosum.*
EL2: SE slope of Pytlácký roh, 1260 m a.s.l., former plant community *Calamagrostio villosae – Piceetum typicum.*
AL1: W slope between Špičník and Březník, former plant community subasociation *Calamagrostio villosae – Piceetum fagetosum.*
AL2: SSE slope of Pytlácký roh, 1310 m a.s.l., former plant community *Calamagrostio villosae – Piceetum fagetosum.*

Clearings:
AP1: SSE slope of Studená hora, 1240 m a.s.l., plant community *Junco effusi – Calamagrostietum villosae.*
AP2: SW slope near Roklanská nádrž, 1185 m a.s.l., plant community *Junco effusi – Calamagrostietum villosae.*
EP2: S slope of Studená hora, 1240 m a.s.l., plant community *Junco effusi – Calamagrostietum villosae.*

Methods

Pitfall traps were used for epigeic activity studies of soil fauna, including Collembola. The used pitfall trap method was described by Absolon (1994), and modified by Tajovský (1996). In the summer period (June 8, 1999 – Aug. 12, 1999) five pitfall traps were exposed on each of the following 9 localities: E0, A0, EL1, EL2, AL1, AL2, AP1, AP2, EP2 In the autumn period (Aug.12, 1999 – Oct. 5, 1999) five pitfall traps were exposed at the above-mentioned sites and on two additional ones (0 and P2). The pitfall content was stored in 38% formaldehyde and the sorted material was than transferred to 96% ethanol. Eight common species of Collembola were identified and counted: *Lepidocyrtus lignorum* (Fabricius, 1781), *Leidocyrus*

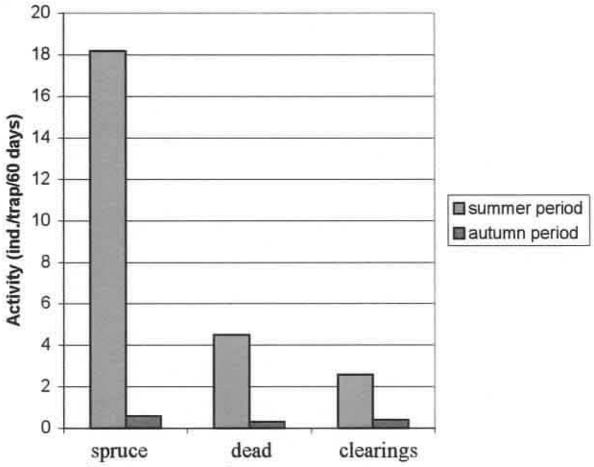

Fig. 1. Activity of *Allacma fusca.*

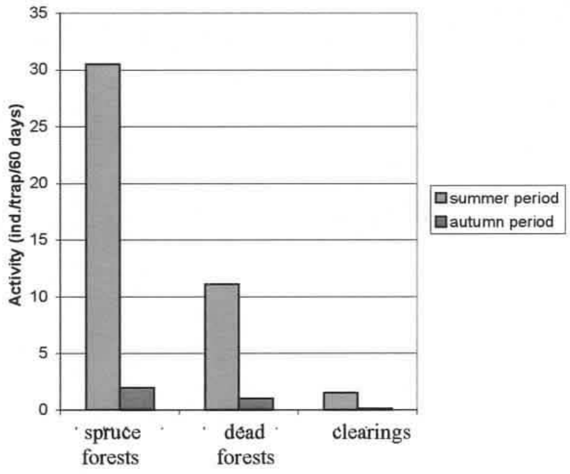

Fig.2. Activity of *Dicyrtomina minuta.*

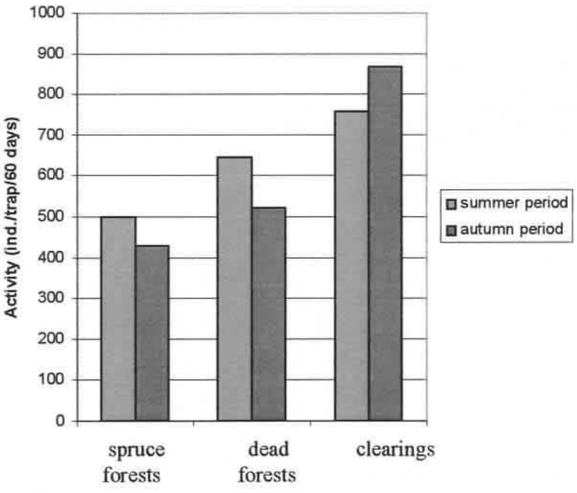

Fig.3. Activity of *Lepidocyrtus lignorum.*

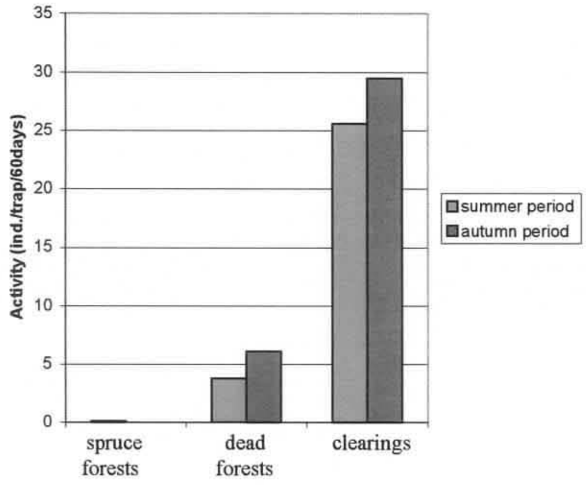

Fig. 4. Activity of *Lepidocyrtu cyaneus*.

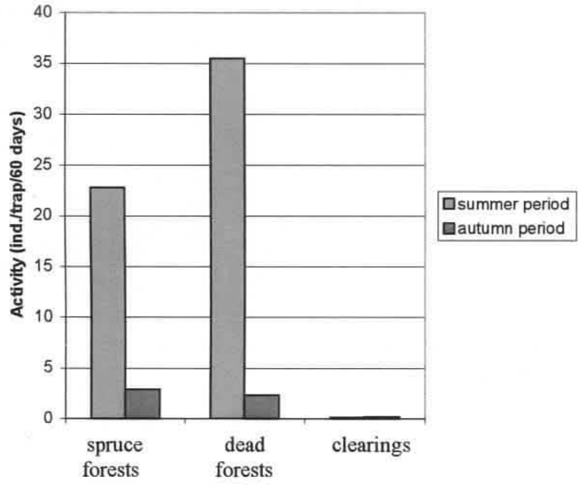

Fig. 5. Activity of *Entomobrya nivalis*.

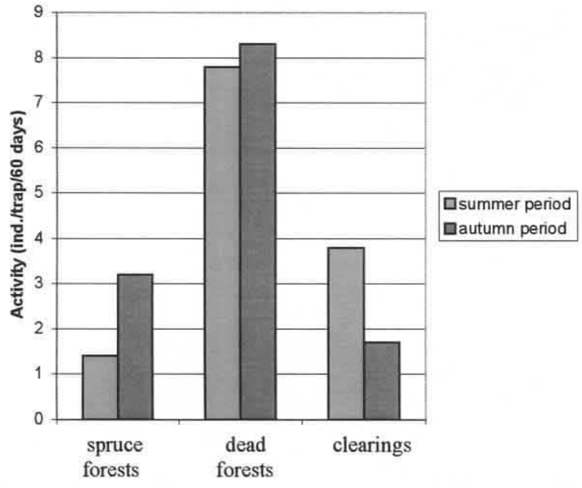

Fig. 6. Activity of *Pogonognathellus longicornis*.

cyaneus (Tullberg, 1871), *Pogonognathellus longicornis* (Müller, 1776), *Tomocerus minutus* Tullberg, 1876, *Tetracanthella stachi* Cassagnau, 1959, *Allacma fusca* (Linné, 1758), *Entomobrya nivalis* (Linné, 1758), and *Dicyrtomina minuta* (Fabricius, 1783). 79 435 specimens were evaluated in this study.

Data analysis

Constancy C, dominance D and activity A of each species was calculated for each combination of season and site. The nomenclature and formulas were used according Tischler (1949). The season was marked by "s" for summer (Cs, Ds, As) and by "a" for autumn (Ca, Da, Aa). Activity was calculated for one trap and 60 days.

Results

Non-damaged spruce forests

The total activity of springtails was low: 714.6 ind.trap^{-1}.60 days^{-1} in summer, and 605 ind.trap^{-1}.60 days^{-1} in autumn. The difference between the time periods was not statistically significant ($P > 0.05$). All studied species, except *L. cyaneus* (C = 10 %) in summer and *L. cyaneus* (C = 0 %) with *D. minuta* (C = 33 %) in autumn, can be considered characteristic (i.e. with C > 50 %). Dominant species were *L. lignorum* (Ds = 70.0 %, Da = 71.0 %), *P. longicornis* (Ds = 19.2 %, Da = 26.3 %) and *A. fusca* (Ds = 4.3 %, Da = 0.3 %). The dominance of the remaining species was below 3 %.

The highest average activity was established for *L. lignorum* (As = 498.8 and Aa = 430 ind.trap^{-1}.60 days^{-1}. The difference between the summer and autumn periods was not statistically significant. Significant differences between summer and autumn period were established only for *A. fusca* (As = 30.5 and Aa = 2.0; P = 0.0009) and *D. minuta* (As = 18.2 and Aa = 0.6; P = 0.0006).

Dead forests

The total activity of springtails was higher than in the non-damaged spruce forests (As = 816.4 and Aa = 696.7 ind.trap^{-1}.60 days^{-1}), but the differences were not statistically significant. *L. cyaneus* (C = 31 %) in the summer period, and *L. cyaneus* (C = 25 %), *A. fusca* (C = 18 %), *E. nivalis* (C = 20 %) and *D. minuta* (C = 30 %) in autumn were not among the characteristic species as their constancy was low. Dominant species were again *L. lignorum* (Ds = 79 %, Da 75.9 %), *P. longicornis* (Ds = 12.1 %, Da = 20.3 %) and *E. nivalis* (Ds = 4.3 %, Da = 0.3 %). The remaining species had a dominance value lower than 3 %.

The highest average activity was established for *L. lignorum* (As = 464.6 and Aa = 520.7 ind.trap^{-1}.60 days^{-1}); the difference between summer and autumn periods was not statistically significant. Activity differences between the summer and autumn periods were significant only for *A. fusca* (As =11.1 and Aa 1.0; P = 0.004), *D. minuta* (As = 4.5 and Aa = 0.3; P = 0.021) and *E. nivalis* (As = 35.5; Aa 2.3; P = 0.0005).

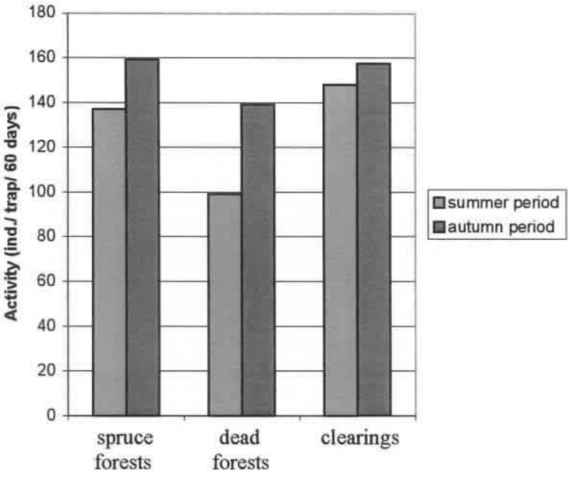

Fig. 7. Activity of *Tetracanthella stachi*.

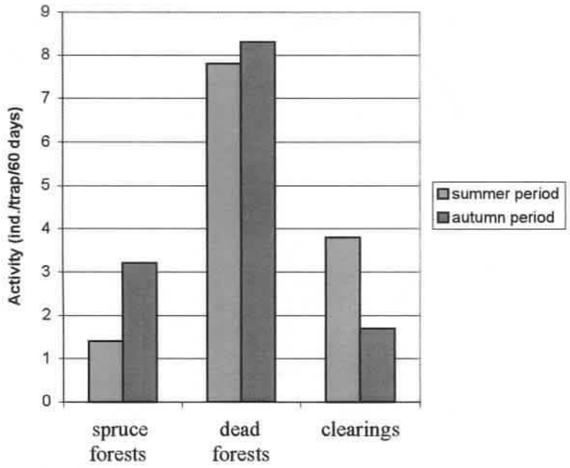

Fig. 8. Activity of *Tomocerus minutus*.

Clearings

The total activity of springtails was higher than in the non-damaged forests (As = 942.8 and Aa = 1061.1 ind.trap^{-1}.60 days^{-1}), but the difference was not statistically significant. *L. cyaneus* (C = 46.7 %) and *E. nivalis* (C = 6.7 %) in the summer period, joined in the autumn by *A. fusca* (C = 10.5 %), *E. nivalis* (C = 15.8 %) and *D. minuta* (C = 31.6 %), were not among the characteristic species. Dominant species were the same as in the undamaged and dead forests: *L. lignorum* (Ds = 80.5 %, Da = 81.8 %), *P. longicornis* (Ds = 15.7 %, Da = 14.8 %) and *L. cyaneus* (Ds = 2.7 %, Da = 2.8 %). The remaining species had D values lower than 1 %.

The highest average activity of a single species was As = 758.6 and Aa = 868.2 ind.trap^{-1}.60 days^{-1} in *L. lignorum*. The difference between the summer and autumn periods was neither statistically significant for *L. lignorum*, nor for *L. cyaneus*, *T. stachi*, *T. minutus*, *E. nivalis*, and *D. minuta*. A significant difference between the summer and autumn periods was established for *A. fusca* only (As = 1.5, Aa 0.1; P = 0.0016).

The Figures 1 – 8 show the activity of the eight studied species. *Allacma fusca* (Fig. 1) had the highest activity in the spruce forests (18 ind.trap^{-1}.60 days^{-1}), a lower one in the dead forests (6 ind.trap^{-1}.60 days^{-1}), and the lowest on the clearings in the summer season. All these differences were statistically significant. Almost the same activity pattern was established for *Dicyrtomina minuta* (Fig. 2). *Lepidocyrtus lignorum* (Fig. 3) had a tended to increase its activity in the direction from spruce forests over thedead forests to the clearings, but the differences were not statistically significant. *Lepidocyrtus cyaneus* (Fig. 4) showed the same activity pattern as *L. lignorum*, but it was almost absent in the non-damaged spruce forests, had a low activity in the dead forests and the highest one in the clearings where it found the best conditions for its development and activity. *Entomobrya nivalis*, an atmobiotic forest species, had its highest activity in the dead forests and the environmental conditions on the clearings were fatal for its life (Fig. 5). *Pogonognathellus longicornis* (Fig. 6) did not show any significant activity differences between the three types ofhabitat, but *Tetracanthella stachi* (Fig. 7) and *Tomocerus minutus* (Fig. 8) found the best conditions for its development in the dead forests.

The low species number under study has limited the outcome of the cluster analysis of all studied sites (Fig. 9). In spite of that, this analysis shows the young dead forest (EL1) with rich understory to be closer to the non-damaged spruce forest (A0) than to the cluster of the clearings and older dead forests.

Discussion

Only eight species of Collembola were determined in this study, because of the large material from the pitfall traps and the limited time available for this study. Pitfall traps were placed at the sites for two months during the summer period and for another two months in autumn. The collembolan community can be divided into 3 – 4 groups according to the effect of the changed environment on the individual species. The first group includes species with highest activity in the forest, decreasing activity in the dead forest and lowest activity on the clearings. *A. fusca* (Fig. 1) and *D. minuta* (Fig. 2) represent this category of forest species. This behaviour could be explained by the high humidity demands of some developmental stages. First larvae of *A. fusca* are highly susceptible to low atmospheric humidity (Betsch and Vannier, 1977) and apparently insufficient moisture levels in the clearings present a limiting factor for their successful development. The second group consists of species increasing their activity in the dead forests and reaching highest activity values in the clearings, for instance *L. cyaneus* (Fig. 4). The forest species *E. nivalis* (Fig. 5), reaching highest activity in dead forests and almost missing on the clearings, is part of the third group together with *T. stachi* (Fig. 7). *L. lignorum* (Fig. 3)

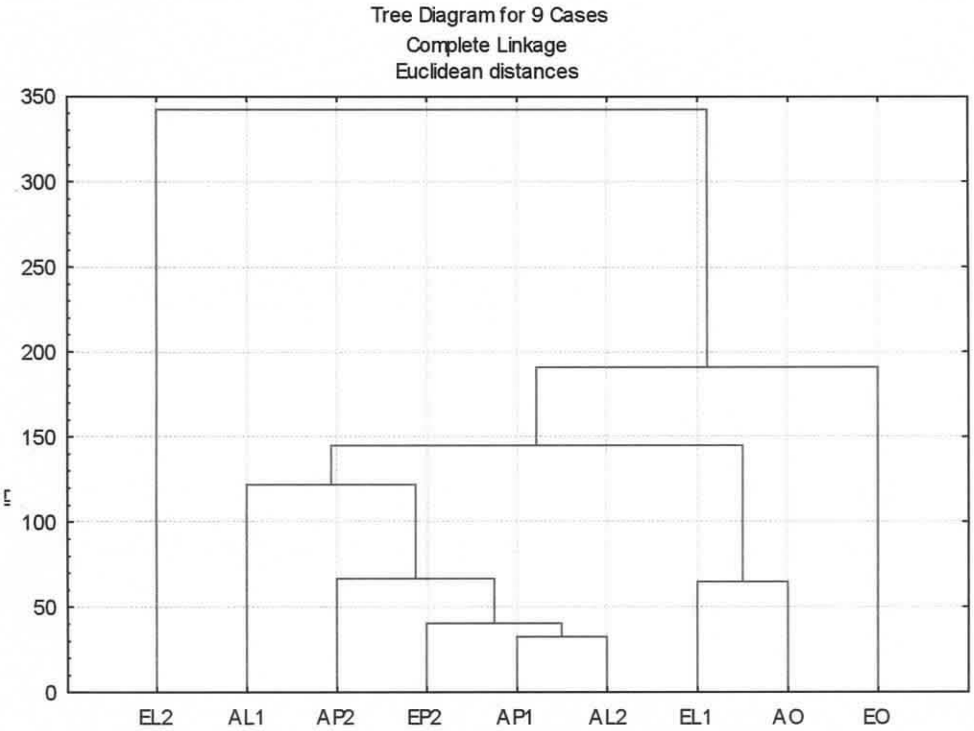

Fig. 9. Cluster analysis of sites based on selected springtail species.

was by far the most active species and its activity was the same in all three habitat types (not significantly different) as was the case for *P. longicornis* (Fig. 6), too. These species present the last group. *T. minutus* (Fig. 8.), showing a strong increase of activity in dead forests and a decrease on the clearings, could be included to the third group.

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